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Efficient Mechanisms to Allocate Assignment Incentives in the Navy

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14. ABSTRACT

In 1973, the United States Navy moved from being a conscription force to being an all-volunteer force. All assignments, however, may not necessarily be voluntary. These assignments (jobs) have been labeled as "hard-to fill" by Navy leadership, and the Navy has implemented market-based, cash stipends to attract Sailors to these jobs. An auction has been determined to be the method used for distributing the stipends. The current format of the auction is often described as a first-price sealed-bid, but it is actually a multi-attribute auction, since the lowest bidder for an assignment may not receive it due to other factors considered in the assignment process, such as skills match, timing, moving costs, etc. This report investigates various auction formats with respect to efficiency, suitability, and feasibility.

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Foreword

This report was prepared to discuss the feasibility and efficiency of various job-market/labor auction mechanisms investigated during the first year (FY02) of the Distribution Incentive System (DIS), a 6.3 research project funded by the Office of Naval Research (ONR) under the FNC ACQUIRE.

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Director

Executive Summary

Background

The U.S. Navy moved from being a conscription force to being an all-volunteer force in 1973. Since that time, Sailors in the Navy have entered as volunteers. Once in the Navy, though, an individual assignment that a Sailor receives is the result of negotiations between him and his detailer (assignment coordinator) and does not always reflect the desires of the Sailor. In fact, there are some shore-based jobs in the Navy that most Sailors strongly prefer not to be assigned to, so much that the Navy offers sea duty credit to compensate Sailors for their assignment to them. However, manning these jobs is still a challenge, and since the Navy needs these jobs filled, Sailors are many times ordered to fill these jobs "involuntarily."

Problem

Recently, in July of 2003, the Navy began an initiative to rectify the hard-to-fill situation. Assignment Incentive Pay (AIP) was authorized by Congress to be paid as a monthly stipend to attract Sailors to volunteer for hard-to-fill assignments. An auction was determined to be the method for distributing the AIP stipends. The current format of the auction is described as a first-price sealed-bid, but it is actually a multi-attribute, or multidimensional auction, since the lowest bidder for an assignment may not receive it due to other factors considered in the assignment process, such as skills match, timing, moving costs, etc. While an auction is typically an efficient mechanism for dispensing resources, the current implementation of a first-price sealed-bid format does not embrace all the complexities of the Navy's assignment process.

Inherent in a multidimensional auction, with multiple factors considered in the assignment of Sailors to jobs (skills match, on-time arrival, Sailor preferences, moving costs, etc.), is the notion of weights, or levels of importance, placed on these various factors. Currently, no explicit weights have been specified for the factors considered in the assignment process for any given partition of Sailors or jobs. The result is that the magnitude of these weights may vary widely across detailing communities, detailers, or even individual assignments. The establishment and incorporation of sound weights is crucial in implementing an auction into the assignment process; otherwise Sailors have no sense of the value of their bid in relation to the assignment they may receive and may have a tendency to inflate their bids, effecting an inefficient, or sub-optimal, outcome.

In addition to monetary incentives, it is conceivable that the Navy may wish to offer non-monetary assignment incentives such as annual leave, follow on assignments, or training, in order to capitalize on any heterogeneity of preferences existent among Sailors. Hence, there is another layer of complexity added to the auction, with both the bids and the determination of the winners being multidimensional in nature. Given that the Navy wishes to use an auction to allocate assignment incentives, the question now becomes, what is the best auction format to use in the Navy's labor market context, in terms of both feasibility and efficiency?

Objective

There are numerous types of auction formats, along with many sets of business rules, which might be considered as alternatives to use in the Navy context. The objective of this report is to consider various types of auction formats, including high-level business rules, and determine (1) the most feasible auction formats, and (2) of these formats, which seems likely to be the most efficient in the Navy context. The results of this report provide the basis for future auction research in the Distribution Incentive System (DIS) project.

Approach

The analysis of auction format alternatives began with a literature review of various auction types and their application to different scenarios. From there, the implementation of an auction in the context of the Navy assignment problem, with its idiosyncrasies, was considered. This report provides an analytical discussion of the four basic types of auctions, first- and second-price sealed-bid, English, and Dutch, taking into account feasibility constraints, high-level Navy objectives, and auction efficiency issues.

Conclusions

The current implementation of a first-price sealed-bid auction, with no explicit weights specified for various factors considered in the assignment process, may not offer the most effective auction format for a Navy assignment auction. Clearly defining the factors to be considered in the assignment of enlisted Sailors and assigning weights that express the Navy's valuation of these factors would (1) allow auction efficiency to be measured in terms other than award level, and (2) enhance efficiency by enabling optimization over the various factors in accord with the specified weights.

With regard to the weights placed on assignment factors, the first-price sealed-bid approach may not afford the Navy the desired readiness outcomes (i.e., skills matching, on-time arrival, right experience levels, etc.) due to the weight that may have to be given to the Sailors' bids. In a first-price sealed-bid auction, the amount that the Sailor bids is directly related to the amount of money he receives for a particular assignment. In fact, if a Sailor is chosen for a particular job for which he bid, then he would receive the amount that he bid. Hence, the question is how low of a weight can be given to the bid before the Sailor feels that the weight is insignificant. In this case, bidding the maximum amount is his best strategy because bidding lower does not affect his chances of receiving the assignment?

The scenario described above is referred to as bid inflation. A second-price sealed-bid may afford the Navy a chance to place a substantially smaller weight on the bid, since in a second-price auction; the bid would have no effect on his payment (he would receive the next highest bid). Nonetheless, regardless of the magnitude of a non-zero weight, it would have some effect on being selected for the job. So, the second-price sealed-bid auction seems promising in that it could enhance readiness outcomes and mitigate bid inflation. The first- and second-price sealed-bid auctions seem to be the most viable options. This research concludes that they should be tested in a laboratory environment to compare efficiency and its relationship to bid inflation.

Contents

Introduction

Despite incremental improvements over time, the current system used to match Sailors with billets still relies heavily on a system designed for a conscripted force. At its worst, the assignments in such a system are driven exclusively by the Navy's requirements, placing negligible weight on Sailor location and job preferences. However, with the advent of the all-volunteer force and with a robust private sector labor demand, the Navy faces a more difficult challenge in that it must compete for the nation's best talent without compromising force readiness. Part of competing means not just attracting talented personnel, but retaining them. Anecdotal evidence increasingly suggests that one of the main sources of Sailor dissatisfaction with Navy employment is the detailing process, in which actual assignments fall short of expectations. This contributes to reduced reenlistment rates and degraded morale, which translates into diminished readiness. Improving the distribution and assignment process affords a promising way of enhancing naval capabilities by improving the lives of its most valuable asset, Sailors.

The current system relies on a centralized, fairly static pay structure in which billets are assigned a salary according to paygrade, but little adjustment is made for hard-to-fill locations or jobs. Although current incentives allow some flexibility for location-specific reenlistment bonuses, the fact that chronic billet gaps persist and Sailors are assigned involuntarily, or "slammed," suggests that the current set of assignment incentives lack the flexibility required to induce voluntary assignments to undesirable billets. Clearly both Sailors and Navy commands would benefit from an improved, decentralized, dynamic incentive structure that more closely resembles a free market than a command and control system. The question then becomes how do we best move from the current scheme that necessitates non-trivial numbers of involuntary assignments to one that affords the flexibility to minimize adverse impacts on morale?

In order to increase the number of volunteer assignments, the Navy currently plans on implementing an auction-based approach to allocating incentives as part of its Sea Warrior Career Management System. This technical note analyzes alternative auction mechanisms and evaluates their appropriateness and efficiency in a Navy context.

The first section provides background material for the project. In particular, it establishes the relationship between the DIS project and the current process. Next, the Navy's and Sailors' competing objectives in the assignment process are highlighted. A brief overview of the current distribution incentives as well as newly proposed ones follows. Finally, a literature review on auctions, highlighting the basic types and the importance of auction design, is included.

At the heart of this document are the results of the analysis phase. The general design guidelines are presented first. A detailed description of the auction design recommendations to select the most promising auction mechanisms is then discussed. A Glossary of Terms used to prepare this report is provided in the Appendix.

Relationship to Current Process

To put the DIS project in perspective it may be beneficial to review the current Navy personnel distribution and assignment (D&A) process. The objective of the D&A process is to match the right person to the right job, at the right time. D&A consists of three distinct functions

with allocation and placement constituting the distribution process, and the assignment or detailing process. While each of these functions is independent, elements of each directly influence the performance or outcome of the others.

1. ***Allocation Function.*** This process of assigning a raw number of available personnel to each Manning Control Authority (MCA). The output of allocation is a document entitled the Navy Manning Plan. The Navy Personnel Command (PERS-45) is responsible for the allocation of both officer and enlisted (E-4 and above). The Enlisted Placement Management Center (EPMAC) is responsible for E-1 through E-3 allocation. During allocation, personnel expected to be available for assignment within a specified future time period are allotted to one of four specific Manning Control Authorities: Atlantic Fleet (CINCLANTFLT), Pacific Fleet (CINCPACFLT), Bureau of Naval Personnel (BUPERS), or Reserves (COMNAVRESFOR), and to either sea duty or shore duty. The objective of allocation is to equitably spread available personnel among these existing and competing requirements. Allocation is the function that addresses fleet balancing issues. The Enlisted Distributable Projection System (EDPROJ) is the principal analytical tool used in the allocation process.

2. ***Placement Function.*** Placement monitors the manning of the various activities. In so doing, a placement officer is considered an activity's advocate. Emphasis is on ensuring that the activity is manned with the right individual, on time and with the correct training. Placement allocates raw numbers of personnel to 4000+ individual commands and generates requisitions for detailers to fill in the assignment process. EPMAC is the principal agent for enlisted placement. This function uses projection information from EDPROJ and priority algorithms from the MCAs.

3. ***Assignment Process.*** Assignment is primarily concerned with matching a particular individual with a particular job based on the needs of the Navy and the needs of the Sailor. The assignment process is most frequently referred to as detailing. It is a centralized procedure employing over 200 detailers in the Bureau of Naval Personnel to assign approximately 130,000 Sailors per year. Twelve months before a Sailor's projected rotation date (PRD), his detailer contacts him and encourages him to start thinking about his next assignment. Sailors are allowed to start negotiating with their detailers for their next assignment within nine months of their PRD. Sailors can gather information about possible job vacancies and apply for desired jobs on-line using the Job Advertisement and Selection System (JASS). Currently, the vast majority of personnel assignments are determined on a first-come first-served basis by telephone negotiations between detailers and Sailors. The detailers, generally considered the Sailor's advocate, spend over 40 percent of their time negotiating with individual Sailors about their next assignments. Studies have shown that much of the discussion between the detailer and Sailor is merely identifying the available and appropriate jobs based on Navy needs and the Sailor's preferences. With different skills, paygrades, and experiences, Sailors must be matched against jobs with various skill, paygrade, and experience requirements. The complex assignment process is made even more complicated by myriad eligibility rules, regulations, and personnel policies associated with personnel assignments. The detailer typically strives to ensure his constituent is assigned to billets of ever-increasing responsibility, whether at sea or ashore. The Enlisted Assignment Information System (EAIS), a COBOL legacy system, is the principal tool for gathering information on

Sailors and jobs in making assignments. The enlisted distribution system has been essentially unchanged for over 20 years.

It may be important to reiterate that the DIS project focuses only on the Assignment (or Detailing) Process.

Assignment Attributes

Assigning a Sailor to a job has several consequences for the Navy as well as for the Sailor. This section outlines examples of measures of effectiveness (MOEs) of an assignment from the point view of the Navy and the individual Sailor. The purpose is to highlight the complexity of satisfying so many, and often conflicting, objectives. The presentations will lead to a new paradigm for classifying the assignment attributes. This paradigm is presented in a section by itself and will prevail throughout the document.

Navy MOEs

A 1998 Science and Technology Report developed to support the Navy Assignment Policy Management System (APMS) describes over 40 potential measures of effectiveness for an assignment. The report classifies the MOEs into seven categories. Those categories and some examples of each are listed below.

Manning MOEs

- Fleet balance
- Percentage of assignments to the four MCAs

Arrival MOEs

- Early and late arrivals
- Requisition priority
- On-time arrival

Budget MOEs

- PCS costs
- Orders costs
- No-cost moves

Policy MOEs

- Women at Sea
- NEC reutilization
- Paygrade match

Location MOEs

- Time at a location

Readiness MOEs

- Percentage of assignments filling a requisition listed on the EPMAC readiness deficiency list
- Percentage of assignments that increase a unit's readiness level
- Actual mission area readiness resulting from the assignments

Other MOEs

- Percentage of CONUS to CONUS moves
- Percentage of CONUS to OCONUS moves

A successful incentive distribution mechanism must be capable of handling any number of the above Navy objectives (MOEs) to support the detailers in finding closer-to-optimum assignments from the Navy policy perspective. On-going Navy projects, such as Improving the Navy's Workforce (INWF), defining jobs in a much more granular fashion with respect to required skills and qualifications, may redefine the way in which some measures of quality-of-fit are measured. However, regardless of exactly how a particular MOE (such as skills match) is determined, the point is that the least cost Sailor for a particular job is not always the best overall match, because there are numerous other MOEs to consider.

Sailor MOEs

The Sailor's view of an assignment may be significantly different from that of the Navy as represented by the detailer or the commands. In particular, a recent study (Butler & Molina, 2002) investigated Sailors' assignment preferences. The study involved 100 Sailors, in their second or subsequent tour, from the Aviation Support Equipment Technician (AS) community. Individual preference information was solicited by means of interviews and focus group questionnaires. The study classifies the E-6 and below Sailors' preferences into five categories, which are listed in descending order of importance:

- Family Life Attributes
- Location Attributes
- Job attributes
- Training and Education attributes
- Incentive Attributes

The study also indicates clearly that those preferences change by paygrade. Hence the above ordering may not be applicable for other paygrades. There are numerous (37) factors presented in this study and undoubtedly others (e.g., the availability of rock climbing opportunities may be very important to a few Sailors) that each Sailor considers when faced with selecting his next assignment. The fact that a Sailor's preferences are so hard to specify is one reason why an auction format offers a promising approach, vice the current method of stating preferences for a location, platform, or type duty. The Sailor reveals through his bid the net result of very personal calculations that he may not even be able to explain very well.

Three Sets of Assignment Attributes

A quick comparison of the Navy and Sailor MOEs presented previously reveals that both parties share very few MOEs. The majority of the Navy MOEs relate to readiness and operational efficiency issues, while the majority of the Sailor's MOEs focus on family and personal advancement issues. The main connection between the Sailor and the Navy MOEs is the incentive package. This suggests differentiating between three sets of Sailor-job assignment attributes.

Negotiable Attributes

Negotiable (or biddable) attributes are the attributes Sailors are allowed to bid on, such as Assignment Incentive Pay (AIP), guaranteed training, curtailed sea duty, assignment credit points, promotion points, etc. It is envisioned that a Program Board, comprised of MCAs, PERS-40, and N-130, will decide on these attributes and document the choices in written policy. Let the vector X denote these attributes.

Navy Attributes

Navy Attributes are the attributes that the Sailors cannot control but are important to the Navy, such as the PCS costs, requisition priority, billet gaps/overlaps, and NEC reutilization. A list of these attributes, which are considered Navy MOEs, is provided. Let the vector Y denote these attributes.

Sailor Attributes

These are the attributes that are important only to the Sailor, such as proximity to family and career advancement potential. That is, these attributes are independent of the Navy MOEs. A list of some of these attributes, which are considered Sailors' MOEs, is provided. Let the vector Z denote these attributes.

In the DIS auction setting, the Sailor would like to achieve his/her family, location and job objectives at the highest possible incentive levels. One advantage of an auction framework is that it gives Sailors some ability to achieve their most important goals by trading off incentives with other job/personal objectives. That is, the Sailors will bid on X accounting for X and Z. On the other hand, the Navy would like to minimize forced assignments at the least possible incentives costs. Thus, the Navy will evaluate an assignment accounting for only X and Y.

Distribution Incentives

The current incentives employed by the Navy are outlined and potential future incentives that are under discussion are described below.

Current Incentives

The following lists some of the incentives currently available to Sailors. Most are entitlements associated with the job but some are negotiable. An appealing aspect of an auction is that a Sailor's bid would reflect both. Everything else being equal a Sailor presumably would bid less on a job offering more incentives. As such, an auction mechanism effectively manages both incentives that are biddable and those that are entitlements associated with the job.

1. ***Overseas Tour Extension Incentive Program (OTEIP)*** – A Sailor who extends a 2-year overseas tour for an additional year is eligible for this additional pay (MILPERSMAN).
2. ***Consecutive Overseas Tours (COTS)*** – A Sailor who serves two full consecutive overseas tours is eligible for additional leave and a round trip ticket home (MILPERSMAN).
3. ***Assignment Incentive Pay (AIP) –*** A market-based, monthly stipend offered to Sailors upon assignment to particular "hard-to-fill" billets. A board comprised of representatives from the MCAs, EPMAC, and PERS-40 determines incentivized locations and maximum award levels. Historical AIP payment information is tracked through the Distribution Incentives Management System (DIMS), a web-based data analysis and visualization tool (NAVADMIN 161/03).
4. ***Location Selective Reenlistment Bonus (LSRB)*** – This bonus is available to a Sailor who qualifies for Selective Reenlistment Bonus (SRB), who reenlists and accepts orders to a location/activity that qualifies for Location Selective Reenlistment Bonus (LSRB) (MILPERSMAN).
5. ***Special Duty Assignment Pay (SDAP)*** - A Sailor who is assigned to certain designated arduous duty billets qualifies for SDAP (MILPERSMAN).
6. ***Tax Free Zones*** – Some locations (primarily the Middle East) are designated by Congress as tax free zones (MILPERSMAN).
7. ***Career Sea Pay*** – Sailors meeting specific criteria are eligible for additional pay while serving on sea duty (MILPERSMAN).
8. ***Cost of Living Allowance (COLA)*** – This component compensates for some excess costs in high cost-of-living areas (MILPERSMAN).
9. ***Hardship Duty Pay-Location (HDP-L) –*** Payable to members for either permanent change of station duty or temporary/deployed/attached duty for over 30 days duration in specified locations. HDP-L is payable to members receiving career sea pay for the same period of service. HDP-L is currently paid to members serving in Afghanistan, Pakistan, Tajikistan, Kyrgyzstan, Uzbekistan, Jakarta, Surabaya, and East Timor, Indonesia (MILPERSMAN).

10. ***En-route Training*** - An En-route Training incentive would offer a Sailor guaranteed training for a specific Navy Enlisted Classification (NEC). Often a Sailor is assigned to en-route training when the billet requires a specific NEC that the Sailor does not hold. In order to truly serve as an incentive, the training would have to be for a skill that the Sailor desires, but is not necessarily required by the billet. Obviously, this has implications in terms of training to meet actual NEC requirements.
11. ***Type 3 Duty*** – Sea Duty credit is given for shore assignments in particularly hard-to-fill locations and/or jobs (MILPERSMAN).
12. ***GUARD 2000 (G2K)*** – This is an incentive where a detailer can offer a Sailor a wider range of jobs (some of which may be lower priority) if the Sailor will obligate for additional years of service (MILPERSMAN).

Potential Incentive

1. ***Assignment Credit Points –*** This type of incentive would offer the Sailor a credit to be used in a subsequent assignment. The Sailor could use the credit to improve his or her effective bid for future job auctions.

Applicable Auction Literature Review

For most goods that consumers purchase, the seller sets a fixed, "take it or leave it" price. When the seller is unsure of the value of the commodity, however, auctions are commonly employed as a useful price discovery instrument. Unusual items (e.g., antiques) and goods whose value fluctuates (e.g., Treasury securities) are often sold in auctions. Arguably the Navy does not have a good sense of what combination of incentives are necessary to generate a volunteer for each available billet, so an auction-type framework may offer a useful mechanism to identify the least-cost, qualified volunteer for each assignment.

There are four basic types of auctions: the English auction, the Dutch auction, the first-price sealed-bid auction, and the second-price sealed-bid (or Vickrey) auction. In the English (or ascending) auction the price is successively raised until there is only one bidder remaining. By contrast in the Dutch (or descending) auction the auctioneer calls out an initially high price and subsequently lowers it until one bidder accepts the price and wins the auction. With a first-price sealed-bid auction, potential buyers submit sealed bids to the auctioneer who then awards the item to the highest bidder who pays his bid. The second-price sealed-bid auction works exactly as the first-price sealed-bid auction except that the highest bidder only pays the bid of the second highest bidder (McAfee & McMillan, 1987a).

From the bidder's perspective the Dutch and first-price sealed-bid auctions are essentially identical. In either case the only genuine option open to him is to bid the highest price he is willing to pay. Thus, in a Dutch auction the good is awarded to the highest bidder at precisely his bid; just as in the first-price sealed-bid auction. Similarly, the English and the second-price sealed-bid auctions are effectively equivalent. Assuming that each person's valuation of the good is independent of how others value it (generally true for the person buying an antique for his home, not resale), then the bidder's dominant strategy is to continue bidding until the price exceeds his willingness to pay. As such, the good will be awarded to the person with the highest willingness to pay at a price equal to the second highest valuation. This is precisely what

happens in the second-price sealed-bid auction (Milgrom, 1989). Furthermore, under a certain set of assumptions (risk-neutrality, private valuations, etc.), the Revenue Equivalence (RE) Theorem shows that the selling price is invariant with respect to the choice of auction format (McAfee & McMillan, 1987a).

There are, however, numerous circumstances under which revenue equivalence breaks down, and auction design matters. Although each job being "auctioned" by the Navy may have some common value component, the valuation of each job likely depends more strongly on independent private valuations. For instance, one attribute of the job may be the quality of secondary education in the area, and each Sailor's valuation of the billet depends (in part) on how much he values school quality. In other words, the fact that others also like high-quality schools does not affect how much he likes high-quality schools. The value that each Sailor places on a job is unaffected by how much others value the job. This is in contrast to an art dealer who makes a valuation on a painting that he intends to resell, which typifies common value auctions. This characterization of Sailor preferences allows us to reduce the complexity of auction design decisions by focusing on those reasons that private value auctions may fail to be efficient.

In the following discussion of the proposed Navy application, it is assumed that the lowest (not highest) bid wins the auction, which is similar to government procurement auctions. One assumption of the Revenue Equivalence Theorem is that bidders are risk neutral, but with as important a decision as one's next job assignment, most Sailors are likely to be somewhat risk averse. This risk aversion may alter their optimal bidding strategies in ways that vary by auction format. The idea is that each Sailor benefits from winning the auction at any price greater than his reservation wage (i.e., the minimum price he is willing to accept). Thus, asking for a large amount is risky because doing so lowers the probability he will win. Risk aversion would then tend to lead him to take less risk by lowering his bid. In such a case it can be shown that a first-price sealed-bid auction produces a lower expected price than the English or second-price auction (Harris & Raviv, 1981; Holt, 1980; Riley & Samuelson, 1981). Similarly, with risk-averse bidders the expected final price is lower when the bidders do not know how many other bidders there are. Thus, if it is possible for the Navy to organize the auction so that each Sailor cannot be sure of the number of bidders, then it should do so (Matthews, 1983; MacAffee & McMillan, 1987b).

Another feature of auctions is that the greater the number of bidders, the lower the expected price (Holt, 1980; Harris & Raviv, 1981). If the auctioneer is concerned about the lack of competitors, a sealed-bid auction may be preferable to an open one. This is because "weaker" bidders (in the Navy case this would be those who would require a high level of incentives to volunteer for a specific billet), know that there is at least a chance that they could win a sealed-bid auction at a price the "stronger" bidder (those who would require a lower level of incentives) would have been willing to match but didn't (Klemperer, 1999). On the other hand, if the auctioneer is less concerned about the lack of competition, then an English may yield a lower price because the Sailor with the highest valuation of the job always has a chance to outbid the "weaker" bidder.

The other main goal when designing an auction is to do so in a way that minimizes the potential for collusion. The opportunity for collusion differs for virtually every auction. As such the auctioneer must assess the potential for risk and design the auction rules accordingly. The fewer the potential bidders and the better they know each other, the greater the risk. At the junior-Enlisted personnel level Sailors are often eligible for a wide range of jobs because they

are still relatively undifferentiated in terms of skills, so collusion poses only a moderate risk. At higher paygrades, where there may be three similar jobs and only three eligible applicants who likely know each other well, the potential for collusion is much greater.

The next question, then, is which auction formats make collusion more difficult. Second-price sealed-bid auctions are particularly susceptible to cheating by the auctioneer—who is to say that the second lowest bid wasn't ten cents greater than the winner's bid? The expectation is that the Navy wouldn't cheat, but if past detailing experiences have left Sailors with little trust in the process, then second-price auctions may be better avoided. The more likely scenario is that some Sailors, especially those in small communities, will be tempted to collude.

English auctions are more susceptible to collusion than Dutch, or sealed auctions for a few reasons. First, in English auctions the bid amounts are sometimes used to signal to others that they will outbid anyone else. In the proposed Navy application, where each Sailor can accept only one job, this may not be a significant drawback because if someone does bid against the signaling bidder, there is no easy way to retaliate later unless a third party wins the auction. Nonetheless, English auctions do provide constant reassurances amongst colluding parties that all members are abiding by the agreement. Furthermore, should anyone cheat he would be immediately recognized, and bidding could proceed as if there were no agreement. This is in contrast to a sealed-bid format where if somebody cheated by deviating from the agreement, this would not be recognized until it was too late. Thus, the level of trust required to maintain collusive agreements is greater with sealed bids. Also, the fact that English auctions necessarily pass through a phase where there are only a few bidders makes them inherently susceptible to collusion. As such, an auctioneer concerned about collusion should consider a sealed bid approach (Klemperer, 2002). In summary, if collusion or lack of competition doesn't present a significant risk, then an English auction may be best; otherwise an auctioneer should consider a sealed-bid auction format.

Although not one of the four major auction types *per se*, the two-sided or double auction offers another alternative. It is typically used when there are multiple sellers and multiple buyers. The bids are offers to buy a certain quantity (assignments) at a certain price and offers to sell a certain quantity (Sailors) at a certain price. The supply and demand schedules are then created and a market price emerges when trading takes place. There are other auction variations that require activity on the part of both the buyers and sellers. Many require a fungible, homogenous good (Goldberg & Tenorio, 1997), but some describe formats in which buyers and sellers both submit bids for a single good (Gibbons, 1992). In this case, if the price offered by the seller is greater (if low price wins, e.g., procurement auction) than the price demanded by the buyer, then a sale takes place at a price that is a predetermined function of the bid-ask spread. Although some experimental work on double auctions has investigated their empirical properties (Hagel & Roth, 1995), there are few theoretical results because of the complexity of modeling strategic behavior of both multiple buyers and sellers (McAfee & McMillan, 1987a). Theory does indicate that some mutually beneficial trades may fail to occur (Gibbons, 1992), but experimental results suggest that empirically it is a minor problem (Hagel & Roth, 1995).

In many respects the Navy application proposed is much like government procurement auctions in that while the price that the government pays is very important, there are other factors involved. Both factors about the bid (what level of quality is the seller promising) and factors specific to the firm (do they have a reputation for fulfilling their promises, cost, etc.) may be used in the determination of the winner. These are different from typical auctions in which who

is buying or selling is irrelevant and what is being sold is fixed and known. However, in many ways they are analogous to the proposed Navy auction in which Sailors differ both in their bids and immutable characteristics such as proximity to new duty station, training, performance appraisals, etc. With these important differences across Sailors, the lowest bid cannot automatically win, but how do you ensure that you obtain the nice efficiency properties associated with auctions? In 1993 an article by Yeon-Koo Che analyzed the case where the bids differ over two possible attributes, but Charles Zheng (2000) was the first to develop theoretical results to guide the creation of an auction in which both the bids and bidders differed across multiple attributes. Although very recent work, the analysis offers some guidance. Zheng argues that the auctioneer should pre-commit to a scoring rule that ranks bidders based on both their bids and private attributes. He also argues that the optimal scoring rule will be one that precludes some from bidding. For instance, an E-1 would never be able to "win" an E-9 billet no matter how low his bid. This optimal auction rule, rather than the bid alone, would identify the winner of the auction. Furthermore, he makes the case for a multi-attribute version of the second-price sealed-bid auction in which each bidder pre-commits to a particular score. The bidder with the best score would then be allowed to adjust the set of variable attributes (in our case the combination of incentives in the Sailor's bid) such that he only had to generate a score equal to the next best bidder.

The findings of an extensive literature review conclude that no such second-price auction has ever been implemented, but the U.S. Department of Agriculture (USDA) currently administers a multi-attribute auction known as the Conservation Reserve Program that employs just such a scoring rule. Farmers submit sealed bids that include the amount of cropland they are offering to idle; environmental characteristics of the land, how the land will be maintained, and the government payment that will make them do this voluntarily. This information is then compiled, a score generated for each bid, and winners announced. This is a $2 billion program that has been in continuous operation since its establishment in 1985. Although significant differences exist between this application of a multi-attribute auction and the proposed Navy labor market application, the USDA's long-term success offers guidance and reassurances that a multi-attribute auction can be successful (USDA, 1999). Although the need for a scoring rule to determine the winner makes the analogy to the Conservation Reserve Program striking, the differences are substantive enough that any proposed Navy application must be thought through very carefully. The following sections of the paper outline alternative mechanisms that might be used to tailor such an auction type framework to meet the Navy's requirements.

Auction Design Guidelines

One of the tasks of the DIS project was to identify the most promising auction mechanisms for assigning Navy requisitions to Sailors. The following four groups of guidelines have influenced the decisions made during the analysis phase. Design recommendations are presented later in this report.

Chief of Naval Operations (CNO) Directives

There are two fundamental CNO directives relevant to the detailing process and the DIS project:

1. CNO goal of zero involuntary assignments.
2. CNO leadership directive for 2002 to " Invest in our Sailors using web-based tools to enhance the flexibility and responsiveness of the detailing process."

These two directives represent the foundation for many auction design recommendations.

The Project Objectives

Based on the above CNO directives, the project team formulated the following general objectives:

1. Maximize the number of volunteer assignments by accounting for Sailors' individual objectives.
2. Minimize over- and under-compensation by determining the true market value of a job, and paying accordingly.
3. Maximize utilization of the state-of-the-art technology, including web-based electronic commerce and decision support systems.

Mechanism Desirable Features

The project team translated the project objectives into specific desirable features for the auction mechanism under consideration. These features include:

1. Give Sailors more and better incentive options to account for their personal preferences.
2. Allow for more incentive flexibility, and allow Sailors to design custom incentive packages.
3. Improve system responsiveness to job imbalances.
4. Increase Sailors' trust in the Distribution and Assignment (D&A) process.
5. Avoid assigning jobs in a sequential nature to obtain closer to optimum assignments.
6. Maximize win-win assignment situations where Navy and Sailor satisfy their MOEs.

Navy Job Market Special Attributes

There are several salient attributes of the Navy job market that affect auction design. To ensure success of the proposed auction mechanism, the Navy job auction design should account for those features. The project team has identified the following special features of the Navy job market:

1. ***Private Value.*** Sailors view jobs differently, that is, a job does not have a value common to all Sailors. This is similar to a person buying an antique for his home, not resale.
2. ***Assign All.*** The Navy has to assign each Sailor. This is unlike commercial auctions where one person wins, and the others go empty-handed.
3. ***Risk Averse Sailors.*** Most Sailors are likely to be somewhat risk averse due to the relative importance of the next job assignment decision.
4. ***Scoring Rule.*** Navy auction needs an easy-to-explain scoring rule to decide on which Sailor is a better fit.

The decisions made regarding the auction design are presented next. The decision statement and the reasoning behind the decision are presented to provide the necessary background and establish a solid base for future discussions.

Auction Design Recommendations

Numerous auction features and designs have been considered and examined during the analysis phase. The objective is to identify the most promising auction mechanisms for assigning Sailors to Navy jobs. Part of this task is to decide which auction types to exclude and which to evaluate in the future experimental phase. This section records the results of the analysis phase and presents the decisions made regarding the design of the experimental auction mechanisms.

In all discussions that follow, an auction is assumed to be a set of jobs for a certain desk code, rating(s) and paygrade(s), during a given window of time.

Recommendation # 1. Two Auction Mechanisms

Recommendation Statement

The focus was only on sealed, one-sided auctions in which most, if not all, the assignments are made in an initial round. Two auction mechanisms seem to have the features the Navy desires and are worthy of further experimentation:

- ***The Invitational Mechanism***, which aims to optimize the Navy Measures of Effectiveness (MOEs) before the auction begins. This is accomplished by selecting for a particular set of available jobs, the set of eligible Sailors who will best satisfy the Navy MOEs within acceptable limits. The selected Sailors will be the only ones who can participate in the auction, and the scoring rule only accounts for the negotiable (biddable) attributes.
- ***The All Eligible Mechanism***, which allows all eligible Sailors to participate. This mechanism uses an expanded scoring rule that will account for both the negotiable attributes and the Navy MOEs.

The main users of these two mechanisms are classified using the following four categories:

1. ***The Career Policy Administrator (CPA).*** Before the auction starts, the CPA will define the group of Sailors and jobs to be included in the auction grouping, select and weight

MOEs and biddable attributes, and set the reservation wages. CPA post-auction activities include reviewing and analyzing auction results.

2. ***Detailers.*** Before the auction starts, the Navy detailers will set soft eligibility rules, exclude Sailors and/or jobs using latest information, and enforce Sailor-job match eligibility rules. During the auction, the detailers will review Sailors' intent to bid, review assignments to confirm match, unassign, or force assign.
3. ***Sailors.*** During the auction, Sailors will express intent to bid and then formulate their bids. Sailors' post-auction activities include reviewing auction results.
4. ***Command Representatives*.** Before the auction starts, command representatives will assign points to desirable Sailor-job matches, accounting for JOB attributes (Take Up Month (TUM), difficulty to fill, and priority), Sailor attributes (EDA, NEC, PCS, EVAL) and subsidy budget data (time of year, remaining budget, projected needs for the remaining of the year).The general framework for the two auction mechanisms is similar, and is envisioned to contain the following individuals and the processes associated with their roles:

- CPA sets auction parameters.
- Detailers set soft eligibility rules.
- Sailors formulate and submit bids.
- Command Representatives determine points to allocate to individual Sailors' fitness scores.Detailers finalize assignments and notify Sailors.
- Sailors review their assignments.CPA reviews and analyzes auction results and compares auctions.**Decision Reasoning and Mechanism Design Recommendations**

Other auction types are excluded, as explained in Recommendations 2, 3, 4, 5, and 7. The following sub-sections discuss the selected mechanisms in further details.

All Eligible Auction (AEA)

For our purposes, a Sailor is said to be ***eligible*** for a job if he satisfies the Navy eligibility rules. These rules include Sailor-job compatibility requirements imposed by timing (PRD and TUM), paygrade, rating, NEC, sea/shore rotation, and MCA.

In this proposal, all Sailors who meet the basic eligibility requirements for each job are eligible to bid for the position. Note that for many jobs no incentive may be authorized so that the bids are constrained to be zero. For ease of exposition, the term bid is used to refer to applications for jobs for which Sailors may or may not request an incentive.

In the All Eligible Auction, Sailors submit sealed bids for all those jobs which they would be willing to accept if offered with their requested incentives. Many jobs, if not most, would constrain bids to be zero. Hard-to-fill billets, however, would have incentives authorized (perhaps by the CPA or a body much like the DIMS Program Board), and non-zero bids below the Navy's reservation price would be considered. Bids would be allowed over multiple incentives (e.g., leave, AIP, and guaranteed training) in order to tailor the incentive package to each Sailor and maintain the flexibility detailers currently enjoy. A pre-announced scoring rule

that reflects Navy MOEs (PCS cost, length of gap/overlap, training cost, requisition priority, etc.) and each Sailor's multi-attribute bid (annual leave, AIP, etc.) creates a single overall fitness score for each job on which the Sailor bid. For transparency and bid determination purposes, an online calculator could allow the Sailor to see how asking for varying combinations of incentives affects his overall score for each billet and hence the probability that he would win the auction. Once sealed bids (zero and non-zero) are submitted, an optimization routine would optimize assignments based on the scoring rule to ensure that the orders issued are those that maximize the net benefit to the Navy.

Command input is incorporated in this scoring. Each command is granted a fixed number of points that could be applied to a particular Sailor's score and hence make it more likely that that Sailor would be chosen for their command. The argument against such command input is that each command doesn't care about big Navy needs or other commands and so their input sub-optimizes the overall Navy-wide assignment outcome. The commands are, however, closer to the "tip of the spear" and may possess information not easily communicated to detailers or incorporated into a scoring rule. This effect of command input enhances the overall Navy assignment outcome. The net effect is likely difficult to empirically test, but this offers a feasible and effective venue for transparent command input.

Invitational Auction (IA)

One concern regarding the above auction design relates to the weight attached to each Sailor's bids. Suppose that in order to "adequately" satisfy Navy operational MOEs that the weight remaining on the bid was "small." The smaller the weight on the bid, the smaller the decrease in the probability of winning the auction if a Sailor increases his bid. In the extreme case of the weight being very small, every Sailor would simply have an incentive to ask for the Navy reservation price, because doing so would negligibly impact whether or not he is awarded a particular assignment. The question then becomes, how big must the weight on the bid be before rational Sailors begin inflating their bids? This is a behavioral implication of auction design that must be tested empirically. It may be that 25 percent is sufficient to preclude much bid inflation and the remaining 75 percent sufficiently accommodates Navy MOEs. It is an empirical question that must be tested.

One solution to the bid-weight problem may be to implement a second-price auction. A second-price sealed-bid may afford the Navy a chance to place a substantially smaller weight on the bid, since in a second-price auction; the bid would have no effect on his payment (he would receive the next highest bid). Nonetheless, regardless of the magnitude of a non-zero weight, it would affect the selection of a Sailor for a job. So, the second-price sealed-bid auction seems promising in that it could 1) mitigate bid inflation since the optimal strategy is to bid truthfully (i.e., the Sailor bids his reservation wage), and 2) enhance readiness outcomes by allowing a higher weight to be placed upon Navy MOEs.

Another solution to this issue is to identify the Sailors who satisfy Navy MOEs within some range, δ, and allow only them to bid on these jobs such that low bidder wins. They would be the "invited" Sailors. This would put 100 percent weight on the bids and eliminate the incentive for bid inflation. The Navy would then optimize across these bids to select the winners in a way that minimizes the overall cost to the Navy.

This approach does, however, lose some flexibility, since the Navy must establish a minimum eligibility cutoff score for every billet or auction. Thus, it may be that the one Sailor, who would volunteer for the assignment for dramatically less incentive than anyone else, and truly wants the assignment, is precluded from bidding. Also, there will always be an inherent tension as to the cutoff fitness for any given billet. The higher the cutoff is, i.e., the fewer the number of Sailors allowed to bid on a given job, the less likely a volunteer will be found, and the greater the perception that this auction format is just used to restrict the available options even further and force Sailors into the jobs the Navy wants them to fill. This is a stark contrast to current Navy initiatives in progress to develop distribution processes that increase the options available to Sailors, especially by presenting opportunities for skill conversion.

Another concern is that there may be a single Sailor who is by far the best match for a particular billet, but if he is not the lowest bidder, he is not selected. Even if the Navy would have gladly paid the difference between his bid and the next lowest bidder, under this format, the lowest bidder always wins.

Also, it signals to Sailors that the auctions may not be as competitive as they would be if all eligible Sailors could bid. This may lead Sailors to inflate their bids on the assumption that they may have more market power with these barriers to entry. Thus, this approach has its drawbacks, and the extent of the bid inflation (if any) under the All Eligible Auction will determine which is the better approach.

The complication of command input is also a concern with this format. Are they given input with respect to who is invited, who is chosen amongst the invited, or both? If input is given amongst the invited, then the bid does not carry 100 percent weight, but perhaps still close enough to preclude bid inflation.

Recommendation # 2. No Open Auctions

Recommendation Statement

In an open auction all Sailors know all bids as they occur. We decided not to consider any open auctions and to focus on only sealed auctions.

Recommendation Reasoning

The reason is that open auctions work best when all participants are online at the same time, which is difficult (if not impossible) to guarantee for all Sailors all the time. Hence, we decided to focus our experimentation on sealed auctions.

Recommendation # 3. No Descending (English) Auctions

Recommendation Statement

We decided not to consider any descending auctions. In a descending auction the Sailors start with their highest bids in the first round and subsequently decrease their bids in the following rounds until there is only one Sailor remaining for each job. In this auction, the Navy announces the best bid (score) for each job after every round. This is the score the Sailors have to beat in the following round to win the job.

Recommendation Reasoning

This auction may be sealed or open.

1. The sealed version (essentially a series of sealed bid auctions) has multiple rounds, hence is not desirable for the reasons described in Recommendation # 7.
2. The open version is not desirable for the reasons described in Recommendation # 2.

Recommendation # 4. No Ascending (Dutch) Auctions

Recommendation Statement

It was decided not to consider any ascending auctions. In an ascending auction the Navy starts by offering jobs for no incentives at all and subsequently increases incentives until one Sailor accepts the offer and wins the job. That is, the first Sailor to accept the Navy's offer wins the job.

Recommendation Reasoning

The reasons are as follows:

1. It is an open auction (see Recommendation # 2).
2. It does not allow Sailors to customize their incentive packages. Sailors must accept an offer made by the Navy instead of expressing their true incentive preferences revealed in a personalized bid.
3. It does not allow Sailors ample time to consider their decisions, as they must make split-second decisions over assignments in real time or risk the job being accepted by someone else.
4. It has the potential of degrading Navy MOEs. The outcomes assume minimal success on selected MOEs, as defined by either the AEA or IA, and are sequentially optimized by bid only.
5. It may be too stressful for the Sailors, since there will likely be many rounds in this format. The Sailors could be faced with several rounds of waiting, uncertainty, and disappointment due to timing issues.

6. The least cost qualified Sailor (and the best fit for the Navy) may be unavailable because he accepted a desirable job with little incentive early rather than risk losing that option in hopes that the compensation offer for a "hard-to-fill" job will increase to the point that it becomes more desirable on net. Thus, the Sailor's risk aversion may lead to poorer matches for both Sailors and the Navy than is available in a sealed bid auction.

Recommendation # 5. One-Sided Auctions

Recommendation Statement

It was concluded that two-sided auctions are less well suited to our circumstances than one-sided.

Recommendation Reasoning

The situations in which double auctions are typically used are not very analogous to this context, and they are not particularly well suited for the Navy labor-market auction. They are typically used when there are multiple sellers and multiple buyers. The bids are offers to buy a certain quantity at a certain price and offers to sell a certain quantity at a certain price. The supply and demand schedules are then created and a market price emerges when trading takes place. There are other auction variations that require activity on the part of both the buyers and sellers. Many require a fungible, homogenous good (Goldberg & Tenorio, 1997), but some describe formats in which buyers and sellers both submit bids for a single good (Gibbons, 1992). In this case as long as the price offered by the seller is greater (if low price wins, e.g., procurement auction) than the price demanded by the buyer, then a sale takes place at a price that is a predetermined function of the bid ask spread. Although some experimental work on double auctions has investigated their empirical properties (Hagel & Roth, 1995), there are few theoretical results because of the complexity of modeling strategic behavior of both multiple buyers and sellers (McAfee & McMillan, 1987a). Additionally, theory indicates that some mutually beneficial trades may fail to occur (Gibbons, 1992).

Unlike most auctions, the proposed auction must solve for each Sailor a "one win only" assignment problem, to which optimization is a natural complement. Since the situations in which double-sided auctions are commonly used differ in some non-trivial areas from the Navy detailing context, the recommendation is that the more tested, well understood, and immediately applicable one-sided sealed bid auctions represent a more promising approach.

Recommendation # 6. Baseline Solution

Recommendation Statement

A baseline solution is an optimal slate of assignments produced by optimizing any combination of the Navy MOEs, which, in turn, provides the optimal MOE values for the slate. We decided to use this baseline, or one derived from it, to analyze future experimental auction results. That is, auction design A is better than auction design B if design A produces assignments with Navy MOE success closer (in the 2-norm sense) to the baseline MOE success. Obviously there may be different ways to define what is "closer" (e.g., 1-norm, infinity-norm or weighted norm), but this baseline does provide a useful benchmark.

Recommendation Reasoning

Baseline solutions provide an objective, scientific, and repeatable method for evaluating different auction designs and results. Using these solutions as the benchmark ensures that Navy objectives are optimized within acceptable limits while providing Sailors more and better options, satisfying the Navy motto of "*Mission First, Sailor Always*."

Recommendation # 7. Single Round

Recommendation Statement

It was concluded that a one-round auction approach in which the vast majority of job matches are made simultaneously provides an approach that better satisfies Navy requirements than a multi-round auction.

Recommendation Reasoning

1. In single-round auctions, Sailors will be motivated to reveal their minimum acceptable incentives in their first bid since they know that there is no second chance to revise their bids. This will make auction management and implementation much easier and will reduce the burden imposed on Sailors.
2. Multiple-round auctions may be more difficult to implement in the Navy setting than single-round auctions. Designing multiple round auctions requires addressing more questions than in single-round auctions. For example,
    - What is the optimal number of rounds?
    - Should the number of rounds be fixed and announced a priori or be flexible based on the level of bidding activity?
    - What is the duration of each round?
    - Should the duration be pre-specified and announced or be flexible based on the level of bidding activity?
3. Multiple-round auctions would put more burden on the Sailors' time than would single-round auctions. The more time Sailors spend engaged in monitoring the auctions and updating their bids and applications, the more distracted they are away from their jobs. This could result in a decrease in workplace productivity or Sailor frustration due to the increased amount of time spent bidding on jobs.
4. Multiple-round auctions would require more Navy management time and resources than single-round auctions.
5. Sub-optimal assignments are more likely in multiple round auctions.
    - If Navy decided to make a few assignments in early rounds of the auction, this would limit the gains from cross-billet optimization.

- On the other hand, if the Navy decides to wait for the final round to make optimum batch assignments then the Sailors will have little motivation to reveal their minimum acceptable bids early and may hold back to the last round, thus degenerating into a single-round auction.

Single-round auctions will give Sailors only one shot at their bids. This underscores the importance of providing Sailors with easy to use decision support tools that can help them formulate reasonable bids accounting for their individual preferences, the available jobs, and the competitive situation.

Recommendation # 8. Unassigned Sailors

Recommendation Statement

Sailors who are unassigned in the first round may be handled in a second round or in the next requisition cycle. If ineligible for the next requisition cycle (because of PRD limitations), and there are no other auction rounds, then the Sailor may be assigned at the detailer's discretion.

Recommendation Reasoning

A single round auction may end with unassigned Sailors in two cases:

1. A Sailor's bid was above Navy RW. This may happen in two cases.
   - Either Navy RWs are not revealed to the Sailors before the auction starts, or
   - The Navy RWs are not presented to Sailors as strict maximums, but rather are breakpoints above which Sailor's fitness for the job will be significantly adversely affected.

2. The Sailor was outbid on all eligible jobs that he applied for in the first round and needs a chance to bid on other eligible jobs that the he did not choose to bid on during the first round. This case will only happen if the Sailor is allowed not to bid on some billets for which he is eligible (see Recommendation # 12).

To some degree, the benefit of a second round will depend on the length of the requisition cycle. Under the current two-week requisition cycle, a second round may be infeasible. In this case, the unassigned Sailors will take part in the next requisition cycle if they are eligible. If not, then the detailer may simply issue them orders in the current requisition cycle. In a longer requisition cycle, however, there will be more Sailors. Hence, there will likely be more unassigned Sailors, as well as the necessary time for an additional round. In this case a second round makes sense in that it would reduce the number of orders issued by fiat.

Recommendation # 9. Unassigned Jobs

Recommendation Statement

Handling unassigned jobs is beyond the scope of the project.

Recommendation Reasoning

Note that there are usually more jobs than Sailors in a typical requisition cycle. Accordingly, there will usually be unassigned jobs. Handling unassigned jobs is out of the scope of the project. That being said, the system must facilitate the provision and analysis of budgetary information to the CPA, who will then decide which jobs warrant authorizing an incentive.

Recommendation # 10. Information Disclosure

Recommendation Statement

It is well known that asymmetric information leads to inefficient markets and is a significant contributor to many market failures. It is envisioned that information about each available assignment will be provided to the Sailor in his portal. The deployed system should strive to enhance the auction outcome by providing the following helpful information.

1. Information to be provided to Sailors before the auction starts may include:
    - Sailor quintile (ranking) on each job relative to other Sailors. This information will help Sailors assess their winning chances while not revealing the number of eligible bidders.
    - Scoring rule including scoring weights for each component.
2. Information to be provided to Sailors after the auction is over include:
    - Winning bids and scores for each job
    - Number of participating Sailors
    - Reason(s) Sailor was not awarded a job

Recommendation Reasoning

There are two primary reasons for disclosing the above information, namely

1. ***To enhance trust.*** Revealing ranking and scoring rule before the auction starts, and winning bids and scores after auction is over, is expected to enhance Sailors' trust in the detailing process.
2. ***To increase chances of success.*** Designing a market with symmetric information is expected to enhance efficiency.

Recommendation # 11. Information Non-Disclosure

Recommendation Statement

The following information will not be disclosed before the auction starts:

1. Distance between a Sailor and his closest competitor(s).
    - If disclosed, Sailors may structure their bids accordingly and inflate their bids in situations where they are one of the best candidates.

- Alternatively a Sailor may decide not to bid if he is a poor candidate. Both cases may lead to a sub-optimal outcome for the Navy.

2. Number of eligible or participating Sailors.
    - Such information facilitates collusion if there are only a few competitors and may encourage a single eligible Sailor to inflate his/her bid.
3. The aggregate fitness score points the command applies.
    - Sailors may inflate their bids in case of strong command recommendation.

Recommendation Reasoning

The following reasoning addresses why not to disclose the information stated above.

- To induce Sailors to reveal their minimum acceptable incentive packages
- To minimize Navy's incentive costs
- To safeguard against collusion

Recommendation # 12. Sailor Not-to-Bid Option

Recommendation Statement

Sailors will have an option not to bid on a billet. Sailors should also have the option not to bid at all and wait for next requisition cycle if they are eligible.

Recommendation Reasoning

One of the major advantages of an auction is to obtain volunteers for jobs. Forcing Sailors to bid on jobs and then constraining bids to not exceed the reservation wage will simply mask "slamming." Thus, the main reason for this decision is to minimize forced assignments. It is always possible a high priority billet may not receive any bids and an involuntary assignment is required. The optimization routine would minimize but not eliminate such outcomes. As such, "slamming" would occur at the discretion of the detailer and only when there were large benefits to the Navy.

Recommendation # 13. Who Wins?

Recommendation Statement

The process will recommend Sailors to jobs if two conditions are met:

1. Sailor bid for the job is below the Navy reservation wage for that job.
2. The Sailor-job assignment is part of the solution of the auction-optimum assignment problem (see Recommendation # 14).

It is envisioned that detailers will address the inevitable exceptions that cannot be captured and addressed in an automated assignment system.

Recommendation Reasoning

The reservation wage limit for bids on jobs safeguards against prematurely exhausting the Navy incentive budget, thus not allowing the Navy to apply incentives to those jobs that need them. The optimization step ensures that the best tradeoffs among the Navy MOEs are made for the current auction.

Conclusions

Summary

The uniqueness of the Navy's job auction context requires that the auction mechanism account for both the Sailors' bids over incentives offered and the Navy's policies and MOEs. In addition to the multiple factors shaping the internal mechanism, there are numerous guidelines and desirable features that help determine an appropriate auction format. These include making no involuntary assignments, implementing web-based decision-support tools and self-service technology into Enlisted distribution, achieving market efficiency in terms of both Sailors' compensation and Navy MOEs, providing customizable incentive packages that capitalize on Sailors' preference heterogeneity, and increasing Sailors' trust in the assignment system.

While the body of literature that specifically addresses this scenario is very limited, many insights were gained from the auction research literature review. This review, together with the above guidelines and identified desirable features, led to the formulation of several recommendations for the Navy job auction. These recommendations are aggregated and summarized below.

- Two mechanisms have been identified as desirable for the Navy job auction: the All Eligible Auction (AEA) and the Invitational Auction (IA). The AEA determines the participants in an auction by screening the applicants for minimum eligibility requirements. The IA enables the Navy to invite Sailors to participate in auctions only for which they meet a certain level of fitness.
- Two-sided auctions and the four basic types of auction format, the English auction, Dutch auction, first-price sealed-bid auction, and second-price sealed-bid (or Vickrey) auction, were evaluated for fit within the Navy job auction context. All implementations of open auctions, Dutch auctions, and two-sided auctions are not well suited to the Navy job auction context. One-sided, first- and second-price auction formats are more feasible formats.
- For the sake of simplicity, efficiency, and time, each auction should be executed in one round, where the vast majority of assignments are made for those participating. Sailors should be able to opt out of an auction they are invited or eligible to participate in, with the caveat that in the case of a Sailor being unassigned by the mechanism, he would be assigned at the detailer's discretion.
- Information such as Sailor scoring weights for each component should be disclosed to the Sailors before the auction to mitigate the effect of asymmetric information. Winning bids and scores for each job, the number of participating Sailors, and reason(s) a Sailor was

not awarded a job should be disclosed to the Sailors after the auction to enhance trust in the system. The distance between a Sailor and his closest competitor(s), number of eligible or participating Sailors, and number of aggregate fitness score points a command applies should not be disclosed to Sailors since this knowledge may entice Sailors to game the auction.

- A Sailor will be considered the winner of an auction if his bid for the job is below the Navy reservation wage for that job and the Sailor-job assignment is part of the solution of the auction-optimum assignment problem.

Areas of Future Experimentation

For certain aspects of the auction, there is no theory than can help us pre-select the correct approach for implementation in the Navy context. Additionally, the knowledge base for best practices to draw from is insufficient, since this type of auction has never been implemented. For these reasons, the following variations in the auction design rules must be experimentally tested to determine the best approaches.

Navy Reservations Wages Computation

The Navy Reservation Wage represents the ceiling, or the maximum incentive amount, the Navy is willing to allocate for a certain billet on the negotiable attributes. Experimentation may test different functions to use to accomplish the following:

1. Identify which billet to bring to the attention of the CPA as a good candidate for incentive authorization.
2. Compute a recommended reservation wage derived in part from analysis of past winning bids and other factors such as
    - Inventory level and scarcity of the billet required skill
    - Billet priority
    - Incentive budget: percentage spent to date and planned for the FY
    - Biddable attributes and their Navy assigned weights
3. Unlike in most auction environments, winning any auction for which one receives a net benefit is not necessarily a good outcome because the Sailor may only "win" one job. As such the Sailor will have an incentive to structure his bids such that he is indifferent across his bids because he doesn't know which one the Navy will pick. The presence of floors and ceiling on the amount of his bid may, however, make this impossible. As such a question of interest in experimental work is the nature of the effect of Navy reservation wage floors and ceilings on the entire bid structure of a Sailor eligible to bid on multiple jobs. Does this artifact of a Navy auction still generate truth telling (bidding one's minimum requirement to be adequately compensated for taking the position) as a dominant Sailor bidding strategy?

It is envisioned that Navy reservation wage will be the same for all Sailors, for any given job. Results of the DIMS project may be of significant value for guiding this task.

Navy Reservation WageHierarchy

The Navy reservation wage may have different structures. We may test any and all of the following options:

1. Test an option of specifying a maximum for each negotiable attribute. In some cases, this will be mandatory. For example, we will have a reservation wage for the AIP payments because legally the payments cannot exceed $1500 per month.

Navy Reservation Wage Disclosure

1. We recommend testing whether or not disclosing the Navy reservation wage for each billet before the auction starts leads to a more efficient outcome. Note that if we do, it may be less likely that Sailors will reveal their minimums and may bid closer to reservation wage.
2. If we do not disclose the reservation wage, then Sailors have no point of reference for structuring their bids, and we may have too many invalid bids, i.e., bids that are above the Navy reservation wage.

Biddable Attributes

We may test different combinations of negotiable attributes. Examples include: monetary incentives (e.g., bonus), and non-monetary incentives (leave, training, and promotion points).

The goal of this testing is to determine the marginal rate of substitute between biddable attributes by the Sailors. In other words, given two biddable attributes, A and B, how many units of biddable attribute A does it take to make the average Sailor indifferent between that quantity of biddable attribute A and one unit of biddable attribute B. Understanding this will help the Navy set weights on the biddable attributes such that at the end of the fiscal year the target expenditures of each of the biddable attributes are achieved.

Second round

Test allowing second round or not. Second round may be used to allow Sailors to revise and re-bid in two cases.

1. Their bid in the first round was above Navy reservation wage.
2. The Sailor was outbid on all jobs in the first round and needs a chance to bid on other jobs in the second round.

If a second round is not allowed, the unassigned Sailors will wait for the next requisition cycle if the Sailor PRD permits. Otherwise, orders will be issued by fiat.

Requisition Cycle Length

Increasing the length of the requisition cycle in an auction setting can effectively increase the number of Sailors and requisitions involved in the auction. This size increase is expected to provide Sailors with more options and provide the Navy with closer-to-optimum assignments. The purpose here is to test this hypothesis and reveal possible hidden consequences, if any.

One such consequence of increasing the number of Sailors and jobs may be to increase the effectiveness of an auction in the higher paygrades by decreasing the probability of collusion. The coordination of the experimentation with requisition cycle lengths and the susceptibility of auction formats to collusion is expected to yield insights into the improved tailoring of the auction environment, not only to the Navy, but also to the various communities and paygrades within the Navy.

Scoring Rules

The purpose of the scoring rule is to assign a single number between 0 and 100 to each Sailor's multi-dimensional bid reflecting the Sailor's overall fitness for the job, which is a measure of the net value to the Navy of that Sailor filling that position. For the invitational mechanism, the scoring rule accounts only for the negotiable attributes. For the all eligible mechanism, the scoring rule accounts not only for the negotiable attributes but also for the Navy MOEs.

The desirable features of such a Scoring Rule are as follows:

- Easy to explain to Sailors and Detailers
- Simple and fair
- Easy to implement and maintain
- Fast to execute, so as not to become a computational bottleneck

There should be one Scoring Rule per auction, which is applicable to all Sailors in that auction. The questions to investigate are

- How do alternative sets of weights on various criteria within the scoring rule affect the resulting slate in terms of Navy MOEs?
- How do alternative sets of weights on the biddable attributes alone generate outcomes that deviate from the baseline solution?
- How small can the weight on the bid be (and equivalently how large can the weight on Navy readiness MOEs be) before rational Sailors begin inflating their bids because they believe their bids do not affect the likelihood that they will be assigned to a particular billet in any meaningful way?
- How does the interaction between the reservation wage and scoring weights affect Navy MOEs?

Invitation List

An important step characterizing the invitational mechanism is to identify a list of "invited Sailors" from the list of "eligible Sailors." The purpose of this step is to identify the list of Sailors invited to participate in a specific auction, and to determine which jobs each Sailor would be allowed to bid on. It is envisioned that mathematical modeling will be used to properly execute this step. In particular, the selection process must satisfy the following conditions:

- First, it must achieve an acceptable level of optimality for the Navy's competing objectives (MOEs).
- Second, the selection process must guarantee that each Sailor has an adequate number of alternative jobs to bid on. A solution that selects few top Sailors to bid and leaves the other Sailors with no options is unacceptable. A solution where the majority of the Sailors have only one job to bid on is also unacceptable.
- Third, the selection process must ensure that all jobs will have at least one eligible bidder. A solution that will leave many jobs without any eligible bidders is unacceptable.

Different approaches must be tested in order to identify the optimal "Invitation List."

Baseline Solution

A baseline solution is a slate of assignments for a particular auction that optimizes Navy MOEs without regard to the Sailors' bids. To properly analyze the results of the auction experiments, the observed values of the Navy MOEs of each tested auction will be compared to the Navy MOEs of the baseline solution. The aim is to establish empirical relationships between auction design parameters and Navy MOEs and, accordingly, to identify the best auction design for the Navy. We are planning to test different approaches to identify the "baseline solution."

Optimum Assignments

To safeguard against "bad" assignments, the Navy will determine the assignments in both mechanisms optimizing on the Sailors' scores. Note that these scores are not identical in both mechanisms of Recommendation #1. The scores of the invitational auction account for the Sailors' bids only. The aggregate fitness scores of the all eligible auction account for the Navy MOEs, in addition to the Sailors' bids.

Collusion

Under certain conditions, any auction format is susceptible to collusion. Below are two important questions with regard to the collusion factor of the auction mechanism in the Navy context.

1. How large does the number of eligible Sailors, who *do not* know each other well, have to be before collusion becomes prohibitively difficult?
2. How large does the number of eligible Sailors, who *do* know each other well, have to be before collusion becomes prohibitively difficult?

Although an auction may elicit a bid for jobs that may otherwise not have any applicants, if collusion is an issue the reservation wage becomes a critically important tool to minimize the payment of economic rent (wages paid over and above what was necessary to entice the Sailor to accept the position). The above experimentation will be helpful in answering the question of how to set reservation wages (wages above which the Navy will not pay) for various paygrades and ratings. In other words we may not want to set the reservation wage for E-9 positions much above what we think will be required to obtain a qualified applicant for fear that collusion will artificially raise the bids to the posted reservation wage. On the other hand, for most E-5 jobs, there is less of a worry of paying economic rent, so setting the reservation wage substantively above the expected required level poses little risk (it will be bid down anyway) and has the advantage of eliciting bids that otherwise would not have been received.

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Appendix

Glossary

AHP	Analytic Hierarchical Process
AHPS	Analytic Hierarchical Process System
AIP	Assignment Incentive Pay
APMS	Assignment Policy Management System
Career Sea Pay	After so many years of accumulated sea duty a Sailor becomes eligible for extra pay for additional sea duty.
COLA	Cost of Living Adjustment
COT	Consecutive Overseas Tour—In exchange for serving two full consecutive overseas tours, a Sailor is eligible for additional leave and a round trip ticket home.
DEA	Data Envelopment Analysis
HDP-L	Hardship Duty Pay - Location: HDP-L is payable to members for either permanent change of station duty or temporary /deployed /attached active duty of over 30 days duration in specified locations. HDP-L is not payable to members receiving career sea pay for the same period of service. HDP-L is currently paid to members serving in Afghanistan, Pakistan, Tajikistan, Kyrgyzstan, Uzbekistan, Jakarta, Surabaya, and East Timor, Indonesia.
JASS	Job Advertisement and Selection System
JMLAM	Job Market and Labor Allocation Model
LSRB	Location Selective Reenlistment Bonus
MOE	Measure of Effectiveness
NUF	Navy Utility Function
OTEIP	Overseas Tour Extension Incentive Program. If a Sailor extends a two-year overseas tour for an additional year, he is eligible for this additional pay.
RW	Reservation Wage
SDAP	Special Duty Assignment Pay (some types of arduous duty is given extra pay)
SUF	Sailor Utility Function
MILPERSMAN	Military Personnel Manual
WBM/IA	Web-based Marketplace/Intelligent Agents
INWF	Improving the Navy's Workforce
EDA	Estimated Date of Arrival

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